

# A New Rugged High Sensitivity Radon Monitor for Remote Stations

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## INTRODUCTION

The radon detector which was operated for ANSTO by MLO, was installed in April 1989 to provide a full year of radon concentrations to assess the utility of such information to the CMDL baseline monitoring program. After a year the data proved to be of interest, and the instrument was easy to operate so it was left in place. Over the 5 years to April 1994, several publications have drawn on data from the radon program [Whittlestone, 1985, 1990, Whittlestone *et al.*, 1991, 1992, 1993; Gras and Whittlestone, 1992]. Radon has been established as a valuable measurement for characterizing air masses and should continue to be measured at MLO.

Scientifically it would be desirable to expand CMDL's radon measurement program to other stations. The major inhibition to this process has been financial, but there was also concern that the instrument was more complex than would be desirable at some stations. MLO is environmentally relatively benign and, because of its size, has the technical capability to maintain a relatively complex instrument. Simply installing a duplicate of the first MLO radon detector would not guarantee success at another observatory. ANSTO has, therefore, been developing an instrument better suited to more remote sites.

MLO has provided an excellent opportunity to assess the requirements of a radon detector, partly because it has much in common with other stations that could benefit from radon measurements, and partly because it has two radon detectors (ANSTO's and EML's), each with different characteristics. ANSTO's new design is superior in all ways to its old one, and it incorporates some of the better qualities of the EML instrument. In line with the design objectives, the main respects in which the new instrument is superior to either of the others is in initial cost, simplicity, low power consumption, and freedom from routine maintenance.

In April 1994 the ANSTO radon detector at MLO was re-built to become the second detector of its type. The first was installed at Cape Grim in February 1994. Prior to this, only a small laboratory prototype had been operated. It is therefore pleasing to be able to report that the new system has performed to specification and required no operator intervention between its installation and writing of this report (July 1994). A detailed report on the new design is being prepared by S. Whittlestone *et al.*, 1994.

## DETECTOR DESIGN

High-sensitivity radon detectors work on the "two-filter" principle. Five stages are involved: (1) All radon decay products are filtered from the inlet air by the first filter; (2) the air passes through a delay chamber where a known proportion of the radon decays; (3) the decay products, which have a concentration proportional to that of the radon, are collected on the second filter; (4) the decay of the radon decay products on the filter is converted to electronic pulses; and (5) a data acquisition and control system collects the data and monitors essential operating parameters.

For brevity the EML detector will be designated "E", the old ANSTO detector "A1" and the new one "A2". Little discussion is required of stage 1. All the instruments have similar filters for filter 1, but rather different flow rates, being 400-, 90-, and 40-L min<sup>-1</sup> for E, A2 and A1 respectively.

Stage 2 involves important design considerations because it is necessary to stop the radon decay products from being plated out on the walls of the delay chamber. E uses the approach of moving the air so fast that the decay products do not have time to stick. In E's design this means that high flow rates (400 L min<sup>-1</sup>) are needed in all flow paths, resulting in high pumping power. A1 had an aerosol injected into the air stream. The decay products became attached to the aerosol which was much less likely to plate out, so it was possible to use a low flow rate (40 L min<sup>-1</sup>). A2 uses the high flow rate idea, but has an internal flow loop which means that the high flow is only through a very low impedance filter. The result is that A2 has the simplicity of E but an even lower pumping power than A1. At 25 watts, the power is about an order of magnitude less than E or A1.

In stage 3, the second filter, A2 again takes the simpler of the approaches used in E and A1. In this case it is A1's fixed filter that is used. But an important step is taken here by using a very fine wire screen that is just as effective as a filter for collecting the decay products, but offers much less flow impedance. This is the only part of the detector that requires routine maintenance, and it should be replaced or cleaned every 1 or 2 years.

The fixed filter has two advantages over the moving-filter design. One is the inherent simplicity. Nothing moves and no external control is required. The other advantage is that all the decay products on the filter are

counted, whereas in a moving-filter system, about half of them decay during sampling before the filter is moved to the counter. Fixed-filter detectors are, therefore, more efficient.

The disadvantage of the fixed filter is that the time response is slow. A1 took about 90 minutes to reach 50% of maximum count rate, whereas E indicates the concentration in well-defined half-hour intervals. A2 is much faster than A1 for reasons that are too complex to explain here. It reaches 50% of maximum response in 30 minutes.

There are applications where the slow response time of A1 makes it necessary to use design E. Many of those applications would be adequately served by design A2, making it unnecessary to compromise on efficiency and increase complexity, as E does, in order to gain the required time response. Stage 4, counting the decay products, is practically identical for all three systems. It involves a zinc sulfide screen scintillator with a photomultiplier to detect the alpha particles, followed by pulse amplifiers, and discriminators.

In the final stage, 5, which includes data acquisition and control, E and A1 need active control of moderately complex systems: a filter tape transport mechanism and particle counter respectively. A2 has no devices to control and in its simplest configuration needs to record only pulses from the alpha counter. Only a very simple device is needed. Real-time requirements could be met by a simple, robust data logger.

## RESULTS

Figure 1 is an example of the results obtained from the new detector (A2) and the EML detector (E). There is no question that A2 is measuring radon. However well a laboratory prototype works, performance must be obtained in the field. The agreement between the results will be considered first. Correlation analysis shows that overall, the correlation coefficient between them is 0.79. The data were grouped using different criteria: groups with a wide range of concentrations had the best correlations. The period shown with its concentration range of about 50 to 500  $\text{mBq m}^{-3}$ , had a correlation coefficient of 0.87, whereas groups with ranges 50 to 300 typically had correlation coefficients of about 0.65. These are consistent with correlations observed between detectors E and A1 that ranged from 0.55 for narrow concentration ranges to 0.97 when the concentrations reached 1000  $\text{mBq m}^{-3}$ . There is some evidence in this limited data set that the correlation is better between E and A2 than E and A1, as expected because of the improved time resolution of A2.

It is instructive to examine the differences between the results. At concentrations below 100  $\text{mBq m}^{-3}$ , the agreement is poor, which can be attributed mainly to counting statistical error. At 60  $\text{mBq m}^{-3}$  the error on a 1-hour value for E is 30% and for A2 is 15%. At higher concentrations, differences are smaller, but not as small

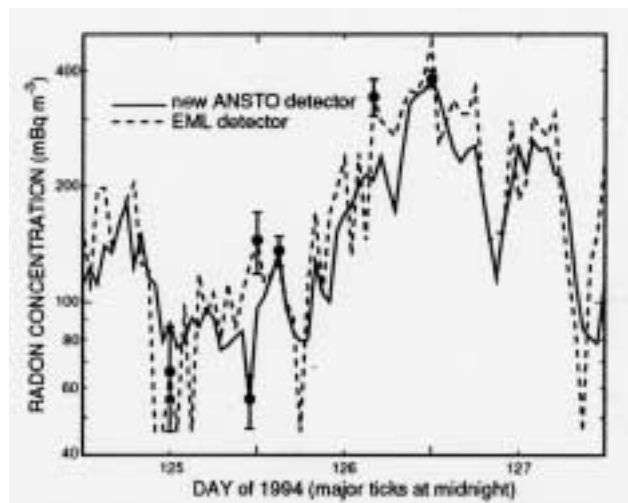


Fig. 1. Radon concentrations at MLO measured by ANSTO and EML instruments.

as could be expected on the basis of counting statistics. These differences are attributed to the better time resolution of E.

## CONCLUSIONS

A new design of baseline radon detectors brought the cost and maintenance requirements down to about the cost of meteorological instruments. Given the power of radon measurements to characterize air samples at remote stations, it is recommended that such measurements be viewed as a necessary component of their basic instrumentation.

The new design has been proven in the field at MLO. It has achieved the same sensitivity as the previous ANSTO radon detector for about half the capital cost, a tenth of the power consumption, and reduction of routine maintenance from weekly to once per year. Because of the simplicity of the design, it is reasonable to expect that unscheduled breakdowns should be less frequent and diagnosis should be much easier.

While the new detector is superior to the old ANSTO design in all respects, the EML design would be preferred in situations when time resolution is of prime importance and concentrations of interest are more than 100  $\text{mBq m}^{-3}$ . At MLO, where the demands of instrument maintenance can be met easily, it is desirable to have both detectors because there are rapid concentration changes, long periods when the concentration is more than 100  $\text{mBq m}^{-3}$ , and periods when the concentration is lower than 100  $\text{mBq m}^{-3}$  and higher sensitivity is necessary.

For a new installation at stations less well staffed than MLO and with a more demanding environment, the new design is to be preferred on cost and maintenance considerations. At Samoa, South Pole, and Barrow, long periods of very low radon concentrations could be

anticipated, which gives a scientific preference for the more sensitive instrument.

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